b.) Remarks

Claims 1-31 are pending in this application. Claims 1, 11-22 have been amended in various particulars as indicated hereinabove.

Neither Marshall nor Church discloses or suggests that a welding wire can work in an alternating current GMAW process. All Welding Textbooks and Encyclopedias teach that GMAW is practiced with direct current in DCEP configuration (attached are 2 pages from Welding Encyclopedia). The difficulty with AC (or even DCEN) welding is rooted in overcoming the instability of the arc during the negative half of the AC cycle. Marshall and Church talk ONLY about the DCEP welding configuration in direct current and never suggest that their wires can be used in AC, which is consistent with the existing knowledge in the industry. Church in Col. 7 line 34 says that his electrodes were E 70 S6 and E 70 S7, which means that the Church welding process is DCEP (attached AWS specification confirms that these wires work only in DCEP, please see the secondnd and the sixth pages).

It was discovered that the claimed composition works in GMAW AC configuration, as claimed, as claimed in amended Claims 1 and 11 which refer to a "gas metal arc" welding process.

Additionally, Applicant emphasizes that the Church electrodes contain no Potassium or its compounds at all (as follows from the same AWS specification I provide).

Additionally, with regard to Marshall, Applicant asserts the following: Marshall mentions that <u>each one</u> of such compounds as graphite, sodium titanate, potassium titanate can be an arc stabilizer in DCEP welding. Conventional metal cored wires, such as in Marshall, are formulated for DCEP and use a whole host of arc stabilizers, generally metallic in nature to avoid access slag formation. This invention, like, for example, in Claim 2 and Claim 15, uses a non-metallic compound K_2MnTiO_4, which is not usually acceptable for DCEP, but in combination with graphite it changes the plasma column in such a way that the arc remains stable in the negative cycle of the AC GMAW process, overcoming the age old stumbling block. There is a big difference between potassium titanate and potassium manganese titanate which Applicant claims.

Applicant is convinced that these reasons distinguish the pendingclaims from Church and Marshall.

Applicants believe that the present application is in condition for allowance. A Notice of Allowance is respectfully solicited. Should any questions arise, the Examiner is encouraged to contact the undersigned.

Respectfully submitted,

HOUSTON ELISEEVA LLP

By Maria Eliseeva

Maria M. Eliseeva
Registration No.: 35,900
Tel.: 781 863 9991
Fax: 781 863 9931

4 Militia Drive. Suite 4
Lexington, Massachusetts 02421
Date: May 25, 2004

Key Words—Carbon steel welding electrodes, carbon steel welding rods, gas metal arc welding, gas tungsten arc welding, metal cored electrodes, plasma arc welding, stranded electrodes

AWS A5.18/A5.18M:2001
An American National Standard

Approved by
American National Standards Institute
February 5, 2001

Specification for Carbon Steel Electrodes and Rods for Gas Shielded Arc Welding

Supersedes ANSI/AWS A5.18-93

Prepared by
AWS A5 Committee on Filler Metals and Allied Materials

Under the Direction of
AWS Technical Activities Committee

Approved by
AWS Board of Directors

Abstract

This specification prescribes the requirements for classification of solid carbon steel electrodes and rods, composite stranded carbon steel electrodes, and composite metal cored carbon steel electrodes for gas shielded arc welding. Classification is based on chemical composition of the electrode for solid electrodes and rods, chemical composition of weld metal for composite stranded and composite metal cored electrodes and the as-welded mechanical properties of the weld metal for each. Additional requirements are included for manufacture, sizes, lengths, and packaging. A guide is appended to the specification as a source of information concerning the classification system employed and the intended use of the electrodes and rods.

This specification makes use of both U.S. Customary Units and the International System of Units (SI). Since these units are not equivalent, each system must be used independently of the other.

American Welding Society
550 N.W. LeJeune Road, Miami, Florida 33126

2.3 ISO Specifications[3]

ISO 864 *Arc welding—Solid and tubular cored wires which deposit carbon and carbon manganese steel—Dimensions of wires, spools, rims, and coils*

3. Classification

3.1 The solid electrodes (and rods) covered by the A5.18 specification utilize a classification system based upon U.S. Customary Units and are classified according to the chemical composition of the electrode, as specified in Table 1, and the as-welded mechanical properties of the weld metal, as specified in Tables 3 and 4. The composite stranded electrodes and composite metal cored electrodes covered by this specification also utilize a classification system based upon U.S. Customary Units and are classified according to the chemical composition and mechanical properties of the weld metal as specified in Tables 2, 3, and 4 and the shielding gas employed.

3.1M The solid electrodes (and rods) covered by the A5.18M specification utilize a classification system based upon the International System of Units (SI) and are classified according to the chemical composition of the electrode, as specified in Table 1, and the mechanical properties of the weld metal, as specified in Tables 3 and 4. The composite stranded electrodes and composite metal cored electrodes covered by this specification also utilize a classification system based upon the International System of Units (SI) and are classified according to the chemical composition and mechanical properties of the weld metal as specified in Tables 2, 3, and 4 and the shielding gas employed.

3. ISO standards can be obtained from the American National Standards Institute, 11 West 42nd Street, New York, NY 10036.

Table 1
Chemical Composition Requirements for Solid Electrodes and Rods

AWS Classification[b]			Weight Percent[a]												
A5.18	A5.18M	UNS[c] Number	C	Mn	Si	P	S	Ni	Cr	Mo	V	Cu[d]	Ti	Zr	Al
ER70S-2	ER48S-2	K10726	0.07	0.90 to 1.40	0.40 to 0.70	0.025	0.035	0.15	0.15	0.15	0.03	0.50	0.05 to 0.15	0.02 to 0.12	0.05 to 0.15
ER70S-3	ER48S-3	K11022	0.06 to 0.15	0.90 to 1.40	0.45 to 0.75	0.025	0.035	0.15	0.15	0.15	0.03	0.50			
ER70S-4	ER48S-4	K11132	0.06 to 0.15	1.00 to 1.50	0.65 to 0.85	0.025	0.035	0.15	0.15	0.15	0.03	0.50			
ER70S-6	ER48S-6	K11140	0.06 to 0.15	1.40 to 1.85	0.80 to 1.15	0.025	0.035	0.15	0.15	0.15	0.03	0.50			
ER70S-7	ER48S-7	K11125	0.07 to 0.15	1.50 to 2.00[e]	0.50 to 0.80	0.025	0.035	0.15	0.15	0.15	0.03	0.50			
ER70S-G	ER48S-G		Not Specified[f]												

Notes:

a. Single values are maximum.

b. The letter "N" as a suffix to a classification indicates that the weld metal is intended for the core belt region of nuclear reactor vessels, as described in the Annex to the specification. This suffix changes the limits on the phosphorus and copper as follows:
P = 0.012% maximum
Cu = 0.08% maximum

c. SAE/ASTM Unified Numbering System for Metals and Alloys.

d. Copper due to any coating on the electrode or rod plus the copper content of the filler metal itself, shall not exceed the stated 0.50% max.

e. In this classification, the maximum Mn may exceed 2.0%. If it does, the maximum C must be reduced 0.01% for each 0.05% increase in Mn or part thereof.

f. Chemical requirements are not specified but there shall be no intentional addition of Ni, Cr, Mo, or V. Composition shall be reported. Requirements are those agreed to by the purchaser and the supplier.

Table 2
Chemical Composition Requirements for Weld Metal from Composite Electrodes

AWS Classification[a]		UNS Number[b]	Shielding Gas[c]	Weight Percent[d]									
A5.18	A5.18M			C	Mn	Si	S	P	Ni[e]	Cr[e]	Mo[e]	V[e]	Cu
Multiple Pass Classifications													
E70C-3X	E48C-3X	W07703	75–80% Ar/Balance CO_2 or CO_2	0.12	1.75	0.90	0.03	0.03	0.50	0.20	0.30	0.08	0.50
E70C-6X	E48C-6X	W07706	75–80% Ar/Balance CO_2 or CO_2	0.12	1.75	0.90	0.03	0.03	0.50	0.20	0.30	0.08	0.50
E70C-G(X)	E48C-G(X)	—	f	Not Specified[g]									
Single Pass Classifications													
E70C-GS(X)	E48C-GS(X)		f	Not Specified[h]									

Notes:
a. The final X shown in the classification represents a "C" or "M" which corresponds to the shielding gas with which the electrode is classified. The use of "C" designates 100% CO_2 shielding (AWS A5.32 Class SG-C). "M" designates 75–80% Ar/ balance CO_2 (AWS A5.32 Class SG-AC-Y, where Y is 20 to 25). For E70C-G [E48C-G] and E70C-GS [E48C-GS], the final "C" or "M" may be omitted if these gases are not used for classification.
b. SAE/ASTM Unified Numbering System for Metals and Alloys.
c. Use of a shielding gas other than that specified will result in different weld metal composition.
d. Single values are maximums.
e. The sum of Ni, Cr, Mo, and V shall not exceed 0.50%.
f. Shielding gas shall be as agreed upon between purchaser and supplier, unless designated by the C or M suffix.
g. Composition shall be reported; the requirements are those agreed to between purchaser and supplier.
h. The composition of weld metal from this classification is not specified since electrodes of this classification are intended only for single pass welds. Dilution, in such welds, usually is quite high.

3.2 Electrodes and rods classified under one classification shall not be classified under any other classification in this specification, except that composite stranded electrodes or composite metal cored electrodes classified as E70C-XC [E48C-XC] may also be classified as E70C-XM [E48C-XM], or vice versa, provided the product meets the requirements of both classifications.

3.3 The welding electrodes and rods classified under this specification are intended for gas shielded arc welding, but that is not to prohibit their use with any other process (or any other shielding gas, or combination of shielding gases) for which they are found suitable.

4. Acceptance

Acceptance[4] of the electrodes and rods shall be in accordance with the provisions of AWS A5.01, *Filler Metal Procurement Guidelines*.

5. Certification

By affixing the AWS specification and classification designations to the packaging, or the classification to the product, the manufacturer certifies that the product meets the requirements of this specification.[5]

6. Rounding-Off Procedure

For the purpose of determining conformance with this specification, an observed or calculated value shall be rounded to the nearest 1000 psi [10 MPa] for tensile and yield strength, and to the "nearest unit" in the last right-hand place of figures used in expressing the limiting value for other quantities in accordance with the rounding-off method given in ASTM E 29, *Standard Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications.*

4. See Section A3, Acceptance (in Annex A) for further information concerning acceptance, testing of the material shipped, and AWS A5.01.

5. See Section A4, Certification (in Annex A) for further information concerning certification and the testing called for to meet this requirement.

Table 3
Tension Test Requirements (As Welded)

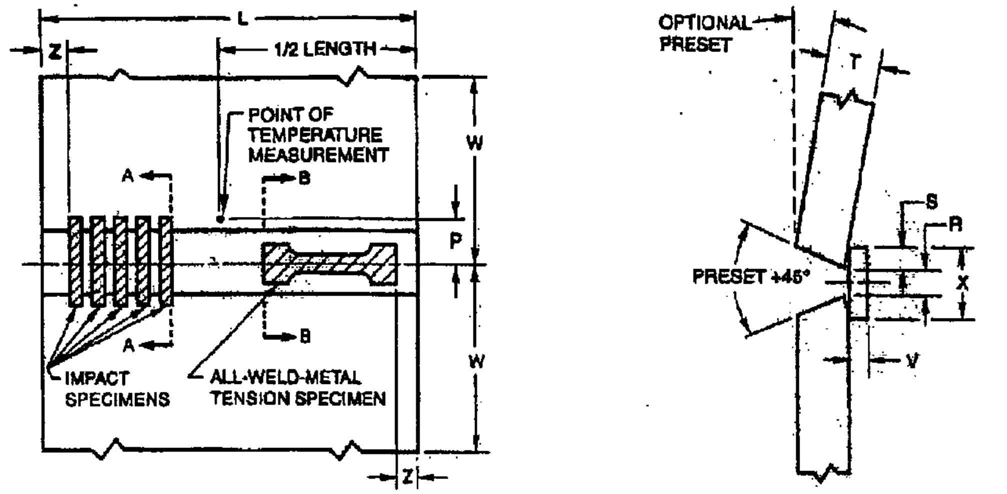
AWS Classification[a]		Shielding Gas	Tensile Strength (minimum)		Yield Strength[b] (minimum)		Elongation[b] Percent (minimum)
A5.18	A5.18M		psi	MPa	psi	MPa	
ER70S-2 ER70S-3 ER70S-4 ER70S-6 ER70S-7	ER48S-2 ER48S-3 ER48S-4 ER48S-6 ER48S-7	CO_2[c]	70 000	480	58 000	400	22
ER70S-G	ER48S-G	d	70 000	480	58 000	400	22
E70C-3X E70C-6X	E48C-3X E48C-6X	75–80% Ar/balance CO_2 or CO_2	70 000	480	58 000	400	22
E70C-G(X)	E48C-G(X)	d	70 000	480	58 000	400	22
		d	70 000	480	Not Specified		Not Specified

Notes:
a. The final X shown in the classification represents a "C" or "M" which corresponds to the shielding gas with which the electrode is classified. The use of "C" designates 100% CO_2 shielding (AWS A5.32 Class SG-C); "M" designates 75–80% Ar/balance CO_2 (AWS A5.32 Class SG-AC-Y, where Y is 20 to 25). For E70C-G [B48C-G] and E70C-GS [E48C-GS], the final "C" or "M" may be omitted.
b. Yield strength at 0.2% offset and elongation in 2 in. [50 mm] gage length (or 1.4 in. [36 mm] gage length for the 0.350 in. [9.0 mm] tensile specimen recommended in A4.2 for the optional acceptance test using gas tungsten arc).
c. CO_2 = carbon dioxide shielding gas (AWS A5.32 Class SG-C). The use of CO_2 for classification purposes shall not be construed to preclude the use of Ar/CO_2 (AWS A5.32 Class SG-AC-Y) or Ar/O_2 (AWS A5.32 Class SG-AO-X) shielding gas mixtures. A filler metal tested with gas blends, such as Ar/O_2, or Ar/CO_2, may result in weld metal having higher strength and lower elongation. Testing with 100% argon shielding (AWS A5.32 Class SG-A) is required when classification testing is based on GTAW only (see A4.2 in Annex A).
d. Shielding gas shall be as agreed to between purchaser and supplier, unless designated by the C or M suffix.

Table 4
Impact Test Requirements (As Welded)

AWS Classification		Average Impact Strength[a,b] (Minimum)	
A5.18	A5.18M	A5.18	A5.18M
ER70S-2	ER48S-2	20 ft·lbf at −20°F	27 J at −30°C
ER70S-3	ER48S-3	20 ft·lbf at 0°F	27 J at −20°C
ER70S-4	ER48S-4	Not Required	Not Required
ER70S-6	ER48S-6	20 ft·lbf at −20°F	27 J at −30°C
ER70S-7	ER48S-7	20 ft·lbf at −20°F	27 J at −30°C
ER70S-G	ER48S-G	As agreed between supplier and purchaser	
E70C-G(X)	E48C-G(X)	As agreed between supplier and purchaser	
E70C-3X	E48C-3X	20 ft·lbf at 0°F	27 J at −20°C
E70C-6X	E48C-6X	20 ft·lbf at −20°F	27 J at −30°C
E70C-GS(X)	E48C-GS(X)	Not Required	Not Required

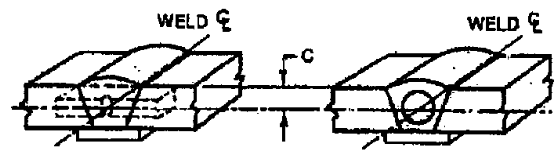
Notes:
a. Both the highest and lowest of the five test values obtained shall be disregarded in computing the impact strength. Two of the remaining three values shall equal or exceed 20 ft·lbf [27 J]; one of the three remaining values may be lower than 20 ft·lbf [27 J], but not lower than 15 ft·lbf [20 J]. The average of the three shall not be less than the 20 ft·lbf [27 J] specified.
b. For classifications with the "N" (nuclear) designation, three additional specimens shall be tested at room temperature. Two of the three shall equal, or exceed, 75 ft·lbf [100 J], and the third shall not be lower than 70 ft·lbf [95 J]. The average of the three shall equal, or exceed, 75 ft·lbf [100 J].



(A) TEST PLATE SHOWING LOCATION OF TEST SPECIMENS

(B) GROOVE PREPARATION OF TEST PLATE

DIMENSIONS		in.	mm
C	Specimen Center		
L	Length, min.		
P	Point of Temperature Measurement		
R	Root Opening		
S	Backup Strip Overlap, min.		
V	Backup Strip Thickness, min.		
X	Backup Strip Width, min.		
T	Thickness		
W	Width, min.		
Z	Discard, min.		



SECTION A–A

(C) ORIENTATION OF IMPACT SPECIMEN

SECTION B–B

(D) LOCATION OF ALL-WELD-METAL TENSION SPECIMEN

TEST CONDITIONS FOR SOLID ELECTRODES[4,5]				
Standard size[6]	0.045 in.	[1.2 mm]	1/16	[1.6 mm]
Shielding gas[7]	CO_2	CO_2	CO_2	CO_2
Wire feed speed	450 in./min ± 5%	[190 mm/sec] ± 5%	240 in./min ± 5%	[100 mm/sec] ± 5%
Nominal arc voltage	27 to 31 V	27 to 31 V	26 to 30 V	26 to 30 V
✓ Resulting current, DCEP[8] (DCEP = electrode positive)	260 to 290 A	260 to 290 A	330 to 360 A	330 to 360 A
Tip-to-work distance[9]	3/4 ± 1/8 in.	[19 ± 3 mm]	3/4 ± 1/8 in.	[19 ± 3 mm]
Travel speed	13 ± 1 in./min	[5.5 ± 0.5 mm/sec]	13 ± 1 in./min	[5.5 ± 0.5 mm/sec]

Notes:
1. Base metal shall be as specified in Table 6.
2. The surfaces to be welded shall be clean.
3. Prior to welding, the assembly may be preset as shown so that the welded joint will be sufficiently flat to facilitate test specimen removal. As an alternative, restraint or a combination of restraint and preset may be used.
4. Test conditions for composite electrodes shall be as recommended by the manufacturer.
5. Preheat and interpass temperatures for both solid and composite electrodes shall be as specified in 9.3.1.
6. If sizes other than 0.045 in. and 1/16 in. [1.2 mm and 1.6 mm] are tested, wire feed speed (and resulting current), arc voltage, and tip-to-work distance shall be changed as needed. This joint configuration is not recommended for electrode sizes smaller than 0.035 in. [0.9 mm].
7. If shielding gases or blends other than CO_2 (AWS A5.32 Class SG-C) are used, the wire feed speed (and resulting current), arc voltage, and travel speed are to be as agreed to between purchaser and supplier.
8. The required combination of electrode feed rate, arc voltage, and tip-to-work distance should produce welding currents in the ranges shown. Currents substantially outside these ranges suggest errors in feed rate, tip-to-work distance, voltage settings, or in instrumentation.
9. Distance from the contact tip to the work, not from the shielding gas cup to the work.

Figure 1—Groove Weld Test Assembly for Mechanical Properties and Soundness

Jefferson's

WELDING ENCYCLOPEDIA

Eighteenth Edition

Edited by
ROBERT L. O'BRIEN

American Welding Society
550 N.W. LeJeune Road, Miami, FL 33126 USA

At the low-current levels for each electrode size, the ve is nearly linear. However, at higher welding cur-ts, particularly with small diameter electrodes, the ves become nonlinear, progressively increasing at a her rate as welding amperage increases. This is ibuted to resistance heating of the electrode exten-) beyond the contact tube.

With all other variables held constant, an increase in ding current (electrode feed speed) will result in following:

1) An increase in the depth and width of the weld etration

2) An increase in the deposition rate

3) An increase in the size of the weld bead

ulsed spray welding is a variation of the GMAW cess in which the current is pulsed to obtain the antages of the spray mode of metal transfer at aver-currents equal to or less than the globular-to-spray sition current.

Since arc force and deposition rate are exponen-y dependent on current, operation above the transi-current often makes the arc forces uncontrollable e vertical and overhead positions. By reducing the age current with pulsing, the arc force and deposi-rates can both be reduced, allowing welds to be le in all positions and in thin sections.

With solid wires, another advantage of pulsed ar welding is that larger diameter wires, i.e., mm (1/16 in.) can be used. Although deposition s are generally no greater than those with smaller eter wires, the advantage is in the lower cost unit of metal deposited. There is also an increase deposition efficiency because of reduced spatter

With metal cored wires, pulsed power produces an that is less sensitive to changes in electrode exten-(stickout) and voltage compared to solid wires. s, the process is more tolerant of operator guidance uations. Pulsed power also minimizes spatter n an operation already low in spatter generation.

Polarity

The term *polarity* is used to describe the electrical nection of the welding gun with relation to the inals of a direct current power source. When the power lead is connected to the positive terminal, polarity is designated as direct current electrode itive (DCEP), arbitrarily called *reverse polarity.* n the gun is connected to the negative terminal, polarity is designated as direct current electrode tive (DCEN), originally called *straight polarity.*

electrical connection of the welding gun

The vast majority of GMAW applications use direct current electrode positive (DCEP). This condition yields a stable arc, smooth metal transfer, relatively low spatter, good weld bead characteristics, and greatest depth of penetration for a wide range of welding currents.

Direct current electrode negative (DCEN) is seldom used because axial spray transfer is not possible without modifications that have had little commercial acceptance. DCEN has a distinct advantage of high melting rates that cannot be exploited because the transfer is globular. With steels, the transfer can be improved by adding a minimum of 5% oxygen to the argon shield (requiring special alloys to compensate for oxidation losses) or by treating the wire to make it thermionic (adding to the cost of the filler metal). In both cases, the deposition rates drop, eliminating the only real advantage of changing polarity. However, because of the high deposition rate and reduced penetration, DCEN has found some use in surfacing applications.

Attempts to use alternating current with the GMAW process have generally been unsuccessful. The cyclic wave form creates arc instability due to the tendency of the arc to extinguish as the current passes through the zero point. Although special wire surface treatments have been developed to overcome this problem, the expense of applying them has made the technique uneconomical.

Arc Voltage (Arc Length)

Arc voltage and *arc length* are terms that are often used interchangeably. It should be pointed out, however, that they are different even though they are related. With GMAW, arc length is a critical variable that must be carefully controlled. For example, in the spray-arc mode with argon shielding, an arc that is too short experiences momentary short circuits. They cause pressure fluctuations which pump air into the arc stream, producing porosity or embrittlement due to absorbed nitrogen. Should the arc be too long, it tends to wander, affecting both the penetration and surface bead profiles. A long arc can also disrupt the gas shield.

With all variables held constant, arc voltage is directly related to arc length. Even though the arc length is the variable of interest and the variable that should be controlled, the voltage is more easily monitored. Because of this, and the normal requirement that the arc voltage be specified in the welding procedure,